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INSOLATION LIMITS INITIAL ESTABLISHMENT OF WESTERN LARCH SEEDLINGS

Raymond C. Shearer [1]

ABSTRACT

During a 2-year study of spot seeding of western larch (Larix occidentalis Nutt.), insolation was the chief cause of death. Effects of insolation were most pronounced on seedlings less than 3 months old on west- and south-facing slopes. Insolation was most severe in early summer if soils were dry. Soil surface temperatures of 130° F. and higher consistently killed seedlings. Successful seeding practices are noted and recommended.

PURPOSE AND SCOPE

Insolation frequently alters the number and distribution of first-year larch seedlings. This paper describes the effects of insolation on young larch seedlings, as influenced by seed pretreatment, screening, aspect, and sowing time. Other agents kill many seedlings, but these are not discussed in this paper.

LITERATURE REVIEW

Insolation has been known to be lethal to seedlings for a half-century

Insolation was first recognized as a factor capable of inflicting heavy first-year seedling losses in the United States when Hartley (1916) described its effect on tree seedlings in the sandy nursery soils of Nebraska. Subsequent studies have shown that high temperature at the soil surface limits the establishment of many species of young seedlings, particularly on the exposed sites of this country (Bates and Roeser 1924; Toumey and Neethling 1924; Haig 1936; Isaac 1938; Smith 1940; and Shearer 1960).

[1]Associate Silviculturist, headquartered at Forestry Sciences Laboratory, Missoula, Montana, which is maintained in cooperation with the University of Montana.

The seriousness of losses due to heat in western larch was first shown by Haig (1936). He identified insolation as the most important agent causing mortality to first-year larch seedlings in full sunlight and in partial shade. No losses from heat occurred under complete shade.

Insolation first produces stem lesions near the ground surface; constriction of the stem follows; then death

The first indication of damage from heat is a water-soaked appearance at the hypocotyl base (Smith and Silen 1963) or a light-colored lesion usually forming on the south or west side of the stem at or near the ground (Toumey and Neethling 1924). Following lesion formation, a shallow constriction forms around the hypocotyl at ground level (Smith and Silen 1963). As the constriction deepens, young seedlings (Douglas-fir up to 4 weeks old) bend to the ground, but older seedlings with good secondary xylem development usually remain erect. Smith and Silen (1963) found constrictions were fatal to Douglas-fir seedlings only when cells collapsed across the pericycle and into the differentiating vascular cambium.

IMPORTANCE OF ENVIRONMENT

Summer climate in western larch range is conducive to insolation of seedlings

Throughout the range of western larch in the northern Rocky Mountains, the summers are characterized by clear, hot, and sunny days; low humidity; high evaporation; and scant rainfall. This region receives 70 to 80 percent of the possible sunshine from June through August (U.S. Dep. Agr. 1941). Because of the large number of clear, hot days, the upper soil dries rapidly and high temperatures are common at the soil surface. Young vegetation, including newly emerged larch seedlings, is especially vulnerable to severe damage or death by the intense heat concentrated at the air-soil interface.

We studied insolation on a cutover area at 4,000 feet elevation where soil was gravelly loam

A recently cutover area on a lower mountain slope on the Coram Experimental Forest was selected for the installation of a spring spot seeding in 1960. Only three-fourths of the germination occurred that year. The remaining one-fourth was delayed until the spring of 1961.

The seed spots ranged in elevation from 3,950 to 4,350 feet. Western larch, Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), Engelmann spruce (*Picea engelmannii* Parry), and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) formerly occupied the area.

The soil was derived from glacial till and was classified as Waits gravelly loam. An average of 31.3 inches of precipitation falls yearly in nearly equal amounts of rain and snow.[2] July and August are usually hot and dry.

[2] Weather records (1948-1963) from Hungry Horse Dam, Mont., 5 miles from the study area.

IDENTIFYING HEAT-KILLED SEEDLINGS

Insolation and damping-off usually show clearly differentiated symptoms

Heat damage to seedlings was identified on the plots by applying the following criteria to differentiate between losses caused by insolation and damping-off fungi:

Insolation	Damping-off
1. Small white lesions on stems frequently distinct near the soil surface.	1. No stem lesions.
2. Constriction of stem at and slightly above the soil surface, but not below.	2. Constriction of stem is limited to soil surface and below.
3. No decay in root below the constriction, and root color is normal light-green to pinkish.	3. Root usually spongy below the constriction and white in color.

FACTORS INFLUENCING INSOLATION

ASPECT

Insolation is most severe on south and west aspects

Severity of insolation was influenced more strongly by the exposure of the seedbed to direct radiation than by any other factor studied. Seedling losses caused by lethal temperatures were most severe on south and west aspects (table 1) where the soil was exposed to direct radiation for long periods. In 1960, six times more seedlings were killed by heat on southerly and westerly aspects than on northerly slopes. These losses increased sharply on all aspects in 1961, because there were more clear, hot days in June 1961 than in June 1960; these hot days caused rapid drying of surface soil and subsequent soil heating. It was the second driest June on record in western Montana, with high maximum temperatures and much sunshine (table 2). In 1961 maximum losses on north slopes due to insolation occurred when the sun was near its summer solstice. The number of seedling deaths caused by insolation on north slopes after July 1 was the same for both years. Seedlings began to die on south- and west-facing slopes 2 weeks sooner than on north-facing slopes, because the soils dried sooner on the more exposed sites.

SCREENING

Screens reduced surface soil temperatures and reduced mortality from insolation in 1961

In addition to providing varying degrees of protection from animals, screens reduce surface soil temperature significantly (Fowells and Arnold 1939; Krauch 1938). Screening did not reduce mortality from excessive heat in 1960, but did reduce the losses in 1961 (table 3).

SEED PRETREATMENT AND SOWING DATE

Seed pretreatment and sowing date influenced germination but not losses from heat

Although both seed pretreatment and date of sowing strongly influenced the germination behavior of the seeds, neither influenced the number of seedlings killed by high surface temperatures. At any inspection date, seedlings 1 week old were no more susceptible to heat injury than those 6 weeks old. In addition, the 1960 losses decreased as the season advanced even though high surface temperatures (138° F.) continued throughout most of August (table 4). Apparently, the seedlings surviving at the end of 1960 grew on more favorable microsites.

RESULTS

Insolation was very destructive in both experiment seasons

Insolation was the chief cause of first-year seedling losses (table 1). The number of seedlings killed by heat was second only to the number killed by drought in 1960. In 1961, insolation was the main cause of mortality. Only newly germinated seedlings were killed by high surface temperatures. Heat damage to the young seedlings started after the surface soil dried and the temperatures at the soil-air interface became extremely hot (possibly between 138° F. and 150° F.).

Measured maximum soil surface temperatures in early July were 150° F.

Temperatures at the air-soil interface.--The symptomatic identification of heat-caused mortality was supported in 1960 by temperature data collected from plots adjacent to the seed spots. Soil surface temperatures were measured on these plots with pellets[3] designed to melt at 113°, 125°, 138°, and 150° F. Maximum surface temperatures often exceeded 150° F. in early July and frequently surpassed 138° F. throughout July. The percent of 138° F. pellets melted and the maximum air temperature during the same period were significantly correlated (table 4). This relationship was not true for the 150° F. pellets. Instead, the area at the air-soil interface that reached or exceeded 150° F. steadily decreased from early July through mid-August, even though the highest air temperatures for the year occurred between the middle and the end of July.

Clear, hot, dry days in late June and early July cause heavy loss from insolation

Table 4 (150° F. column) shows that maximum surface temperatures may occur while the sun is at or near its summer solstice. In years with many clear, dry days--especially in June and in early July, as was true in 1961--insolation causes greater losses than in years with less sunshine, as in 1960. These losses began and peaked 3 weeks earlier in 1961 than in 1960 (fig. 1). About 57 percent of this mortality occurred between June 19 and 29, 1961, whereas the first heat-caused losses in 1960 were not identified until July 7.

[3] Tempils sold by Tempil Corporation, New York, N. Y. Use of trade name is solely for convenience in identification and does not constitute endorsement by the U.S. Forest Service.

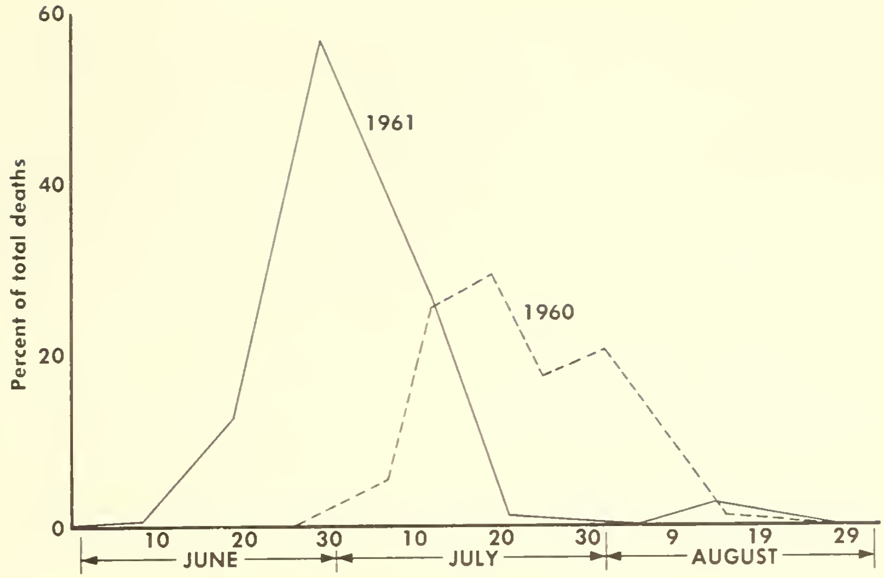

Figure 1.--Insolation-caused mortality by date.

DISCUSSION

Larch seedlings exposed to high temperatures are susceptible to injury or death

Temperatures greater than 138° F. are common at the soil-air interface during July and August on bare seedbeds. Temperatures are more likely to reach 138° F. on south and west aspects than on north slopes. Larch seedlings exposed to this temperature are very susceptible to injury or death. Bates and Roeser (1924) found that sustained temperatures of 130° F. could seriously injure seedlings when the soils were drying. Baker (1929) concluded that 1- to 3-month-old seedlings were readily killed by temperatures of 130° F. but survived at temperatures a few degrees lower. Lorenz (1939) showed that the cortical parenchyma cells of several conifers and hardwoods were killed within 30 minutes at temperatures from 134° F. to 138° F. and within 1 minute at 149° F. to 156° F.

Susceptibility to heat injury seems not to be correlated with age

This study, like several others (Lorenz 1939; Shirley 1936; Smith and Silen 1963), failed to show a correlation between seedling age and susceptibility to heat injury. Smith and Silen (1963) concluded if heat tolerance is greater in older seedlings, it has a physiological rather than an anatomical basis.

From a laboratory test, Shirley (1936) concluded that the cooling effect of transpiration probably provided the greatest protection to young seedlings against excess heat in dry air.

RECOMMENDATIONS

Limit seeding of larch to north aspects

Direct seeding of western larch cannot be recommended on south and west aspects because of the extreme risk of losing most of the seedlings to high surface soil temperatures. Larch stands sometimes are established on such slopes following fires or other disturbance, but foresters cannot afford to distribute millions of seeds per acre, as nature often does, to insure successful regeneration. Seeding should be limited to northerly slopes unless insolation can be reduced by some means on the exposed aspects.

SUMMARY

The installation of an experiment in spot seeding western larch on the Coram Experimental Forest in 1960 showed that insolation killed many new seedlings during their first growing season. Nearly three-fourths of the germination occurred in 1960, but the remainder held over until 1961. Other observations from this experiment were:

1. Lethal temperatures caused the greatest loss of larch seedlings.

2. Direction of slope was the most important factor related to insolation-caused deaths. Many more seedlings on south and west aspects were killed than seedlings growing on north slopes.

3. Seed pretreatment and sowing time had no significant influence on the number of young western larch seedlings killed by insolation.

4. Protection by screens did not reduce mortality in 1960; but in 1961, a very hot, dry year, the wire mesh screens reduced the number of deaths.

5. Insolation-caused losses started after the surface soil dried. These deaths began on north-facing slopes 1 to 2 weeks later than on south or west aspects.

6. Mortality caused by insolation occurred within 3 months after germination.

7. Direct seeding should be practiced only on north-facing slopes, where losses from heat are least.

Table 1. --Mortality of first-year western larch seedlings, by year, aspect, and agent

Year	Aspect	Cause of mortality						
		Insolation	Drought	Fungi	Frost	Clipping	Other	Living
		Percent						
1960	North	6	36	8	13	6	5	26
	South and west	37	30	13	5	6	4	5
	Average	30	32	12	7	6	4	9
1961	North	24	12	16	5	1	5	37
	South and west	47	16	23	4	4	4	2
	Average	42	15	21	4	4	4	10

Table 2. --Possible sunshine measured at Missoula, Montana,[1] for June, July, and August in 1960 and 1961

Year	June	July	August
	Percent		
1960	67	91	59
1961	83	85	74
Average (1950-1962)	60	81	72

[1]Although Missoula is about 100 airline miles from the study area, it is believed the percent of sunshine is very nearly equal at both locations.

Table 3. --Mortality of first-year western larch seedlings, caused by insolation, as influenced by degree of shading and by year of germination[1]

Year	Degree of shading		
	Open	3 mesh per inch	1 mesh per inch
	Percent		
1960	36	37	36
1961	70	56	51

[1]Seedlings surviving earlier losses.

Table 4. --Influence of date and maximum air temperature on the temperature at the soil-air interface, in 1960

Date	Maximum air temperature	Temperature pellets melted	
		138° F. pellet[1]	150° F. pellet
	Degrees F.	Percent	
July 6-12	90	69	42
July 13-21	100	97	34
July 22-29	89	27	25
July 30-August 3	94	60	21
August 4-14	87	17	4
August 15-18	80	0	0

[1]Highly significant correlation (r = .92) between maximum air temperature and percent of 138° F. pellets melted.

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AFPS, Ogden, Utah